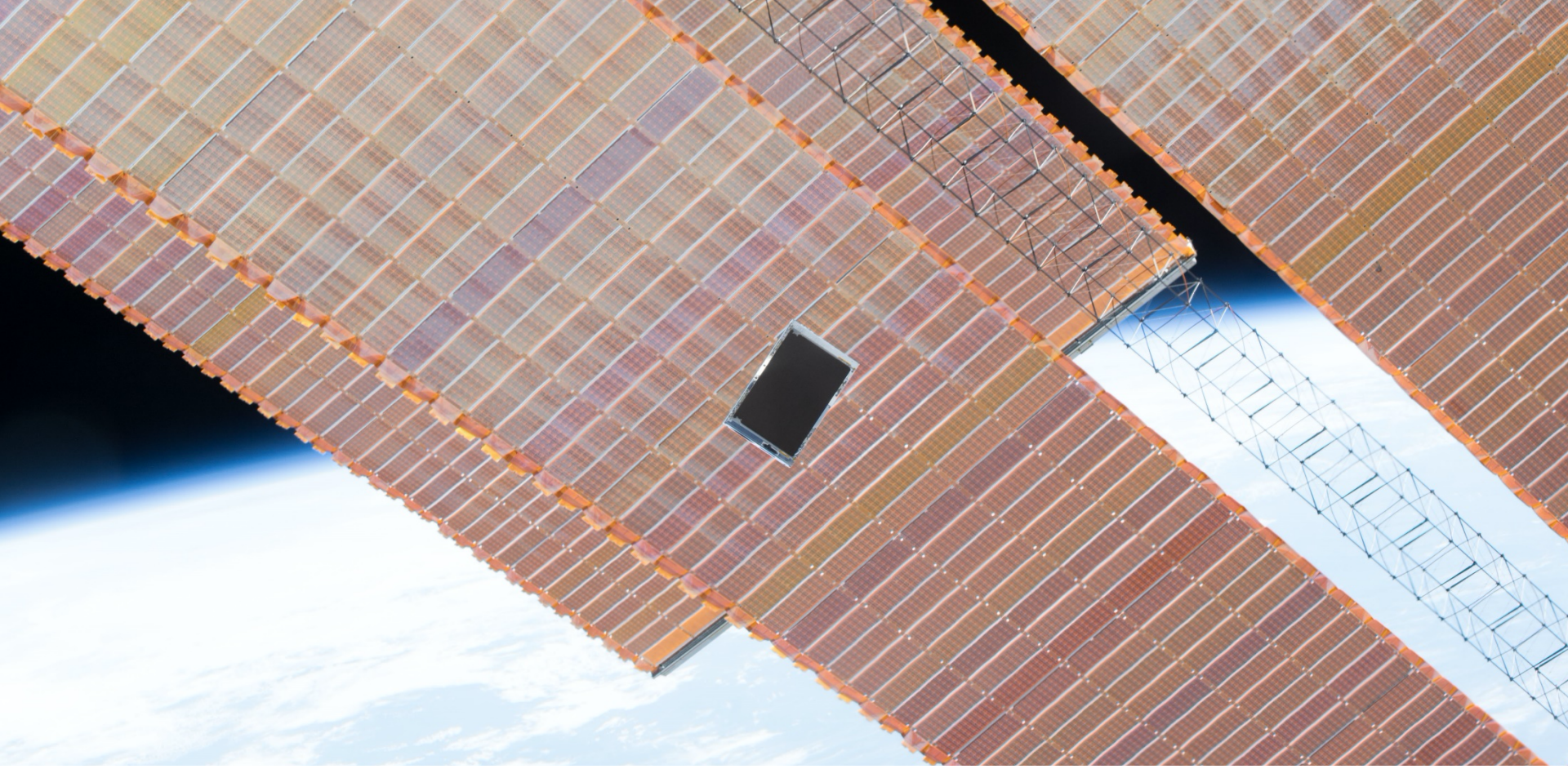

ASTERIA

A CubeSat Enabling High Precision Photometry in a Small Package

Matthew W. Smith[1], Mary Knapp[2], Sara Seager[2], Christopher Pong[1], Amanda Donner[1], Brian Campuzano[1], Peter Di Pasquale[1], Colin Smith[1], Joel Krajewski[1], Mary White[1]

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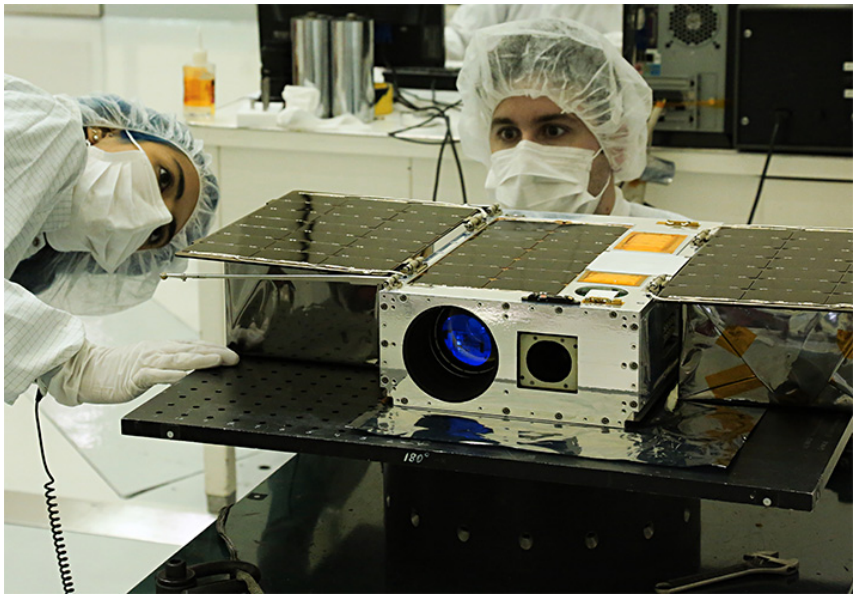
Jet Propulsion Laboratory
California Institute of Technology

ASTERIA

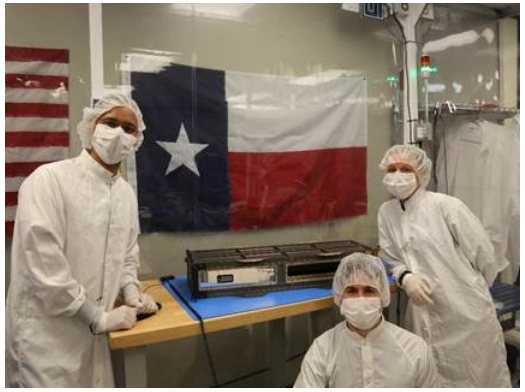
Arcsecond Space Telescope Enabling Research In Astrophysics

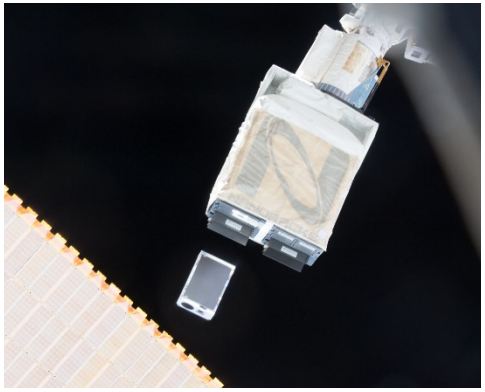
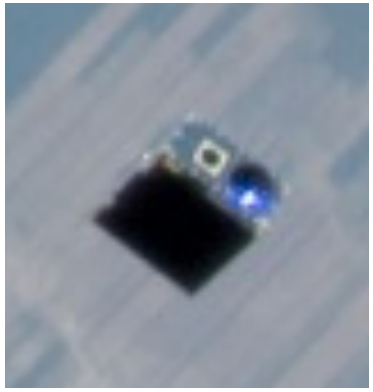
- Prime mission: Demonstrate precision pointing and precision thermal control technologies in a nanosatellite platform
- Extended mission: Further characterize hardware and software components, conduct dedicated science observations
- 6U CubeSat (approximately 11 x 24 x 37 cm^3, 10.2 kg)
- JPL and MIT collaboration
- Sara Seager, PI
- Built, tested, operated at JPL
- Ground station at Morehead State University (Kentucky)
- Funded through JPL's Phaeton Program for early career training plus MIT contributions to ops
- 230+ days of operation in space



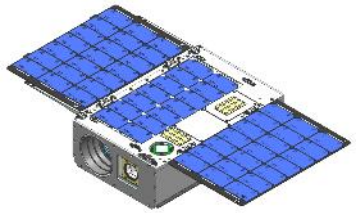
Mission Timeline

- 1 Jun 2017 Delivery to NanoRacks (Houston, TX)
- 14 Aug 2017 Launch (SpaceX F9/Dragon, CRS-12)
- 20 Nov 2017 Deployment from ISS
- 21 Nov 2017 Initial acquisition, start of checkout
- 8 Dec 2017 First image acquisition
- 18 Dec 2017 First successful precision pointing checkout
- 1 Feb 2018 Achieved L1 tech demo requirements
- Feb-May 2018 Extension 1 (component testing, opportunistic science)
- May-Sep 2018 Extension 2 (science focused)



Spacecraft



Solar Array
MMA Design

Payload Electronics Assembly
JPL / Ecliptic / Spaceflight

Optical Telescope Assembly
JPL

239 mm

116 mm

Interface Board
JPL

Electrical Power Subsystem / Battery
GomSpace

Radio and Antennas
Vulcan Wireless

ADCS
Blue Canyon Technologies

366 mm

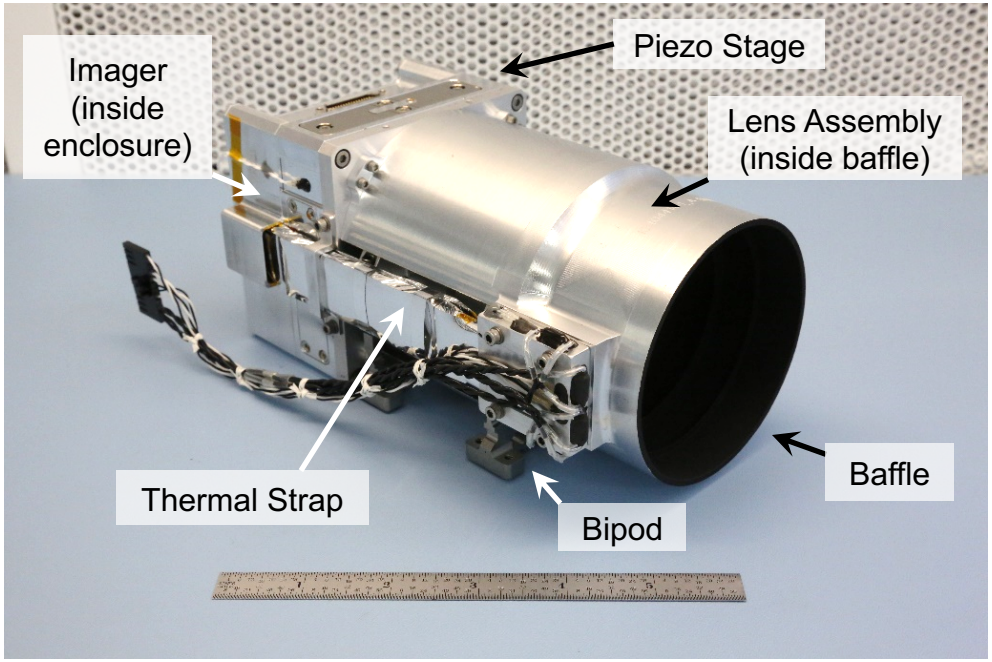
Mechanical Chassis
JPL

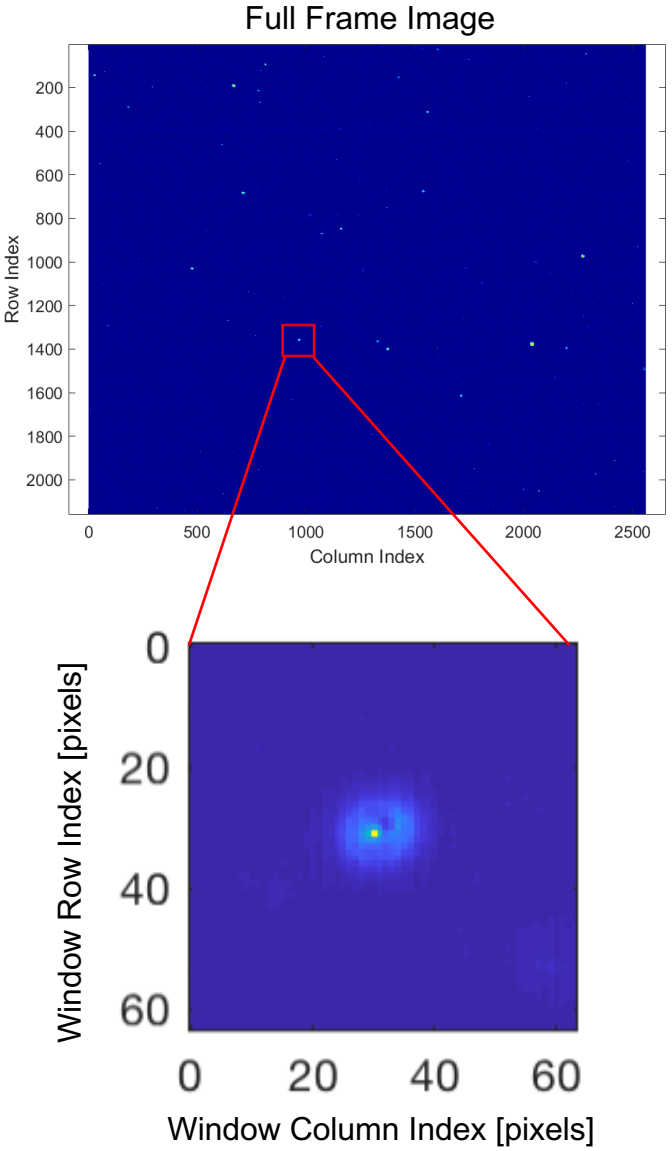
Flight Software
JPL (F Prime)

PCS Software
JPL

MOS Software
JPL / Alethium

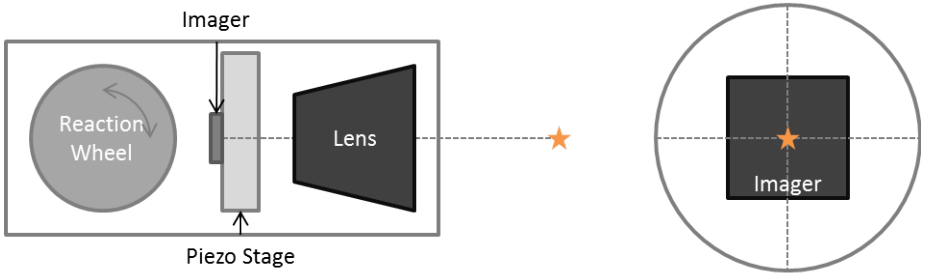
Optical Telescope Assembly





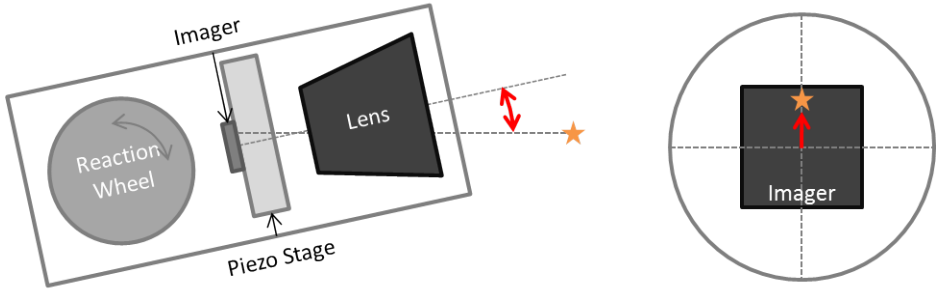
Pointing Control Approach

1



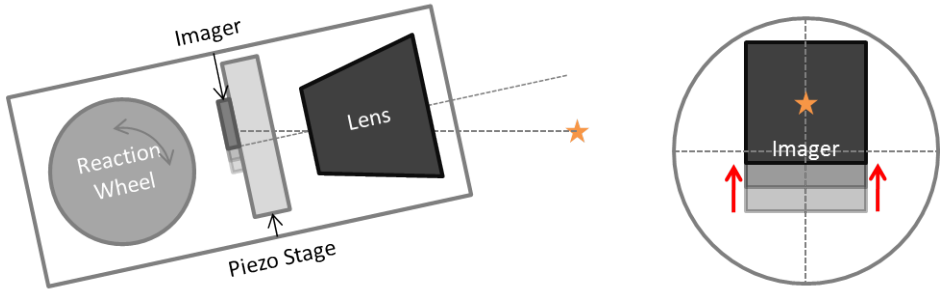
Reaction wheels point the spacecraft to the target star

2

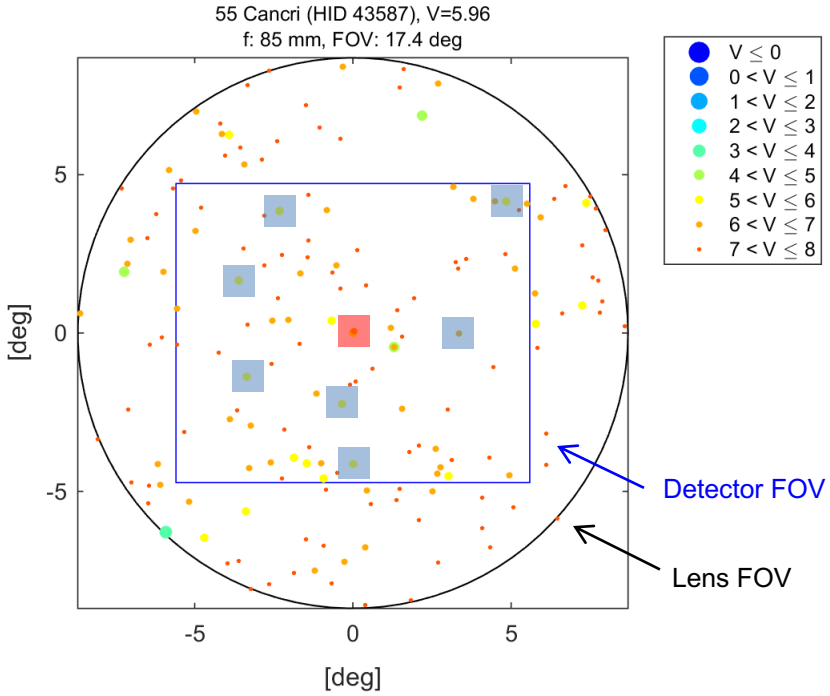


Attitude errors will cause the target star to shift on the imager

3



Piezo stage shifts the imager to compensate for attitude errors



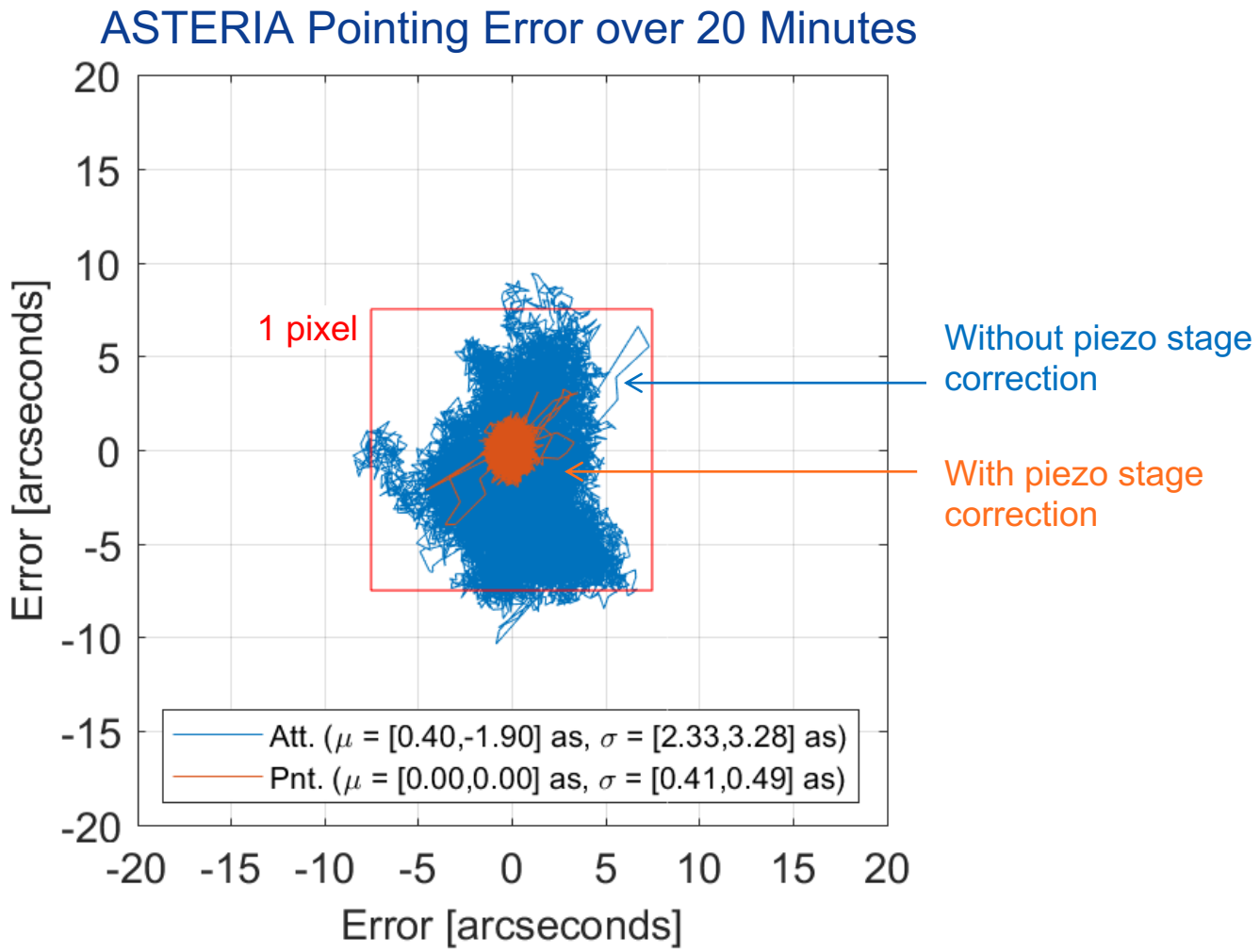
Target star window

Guide star windows

Windows read at 20 Hz

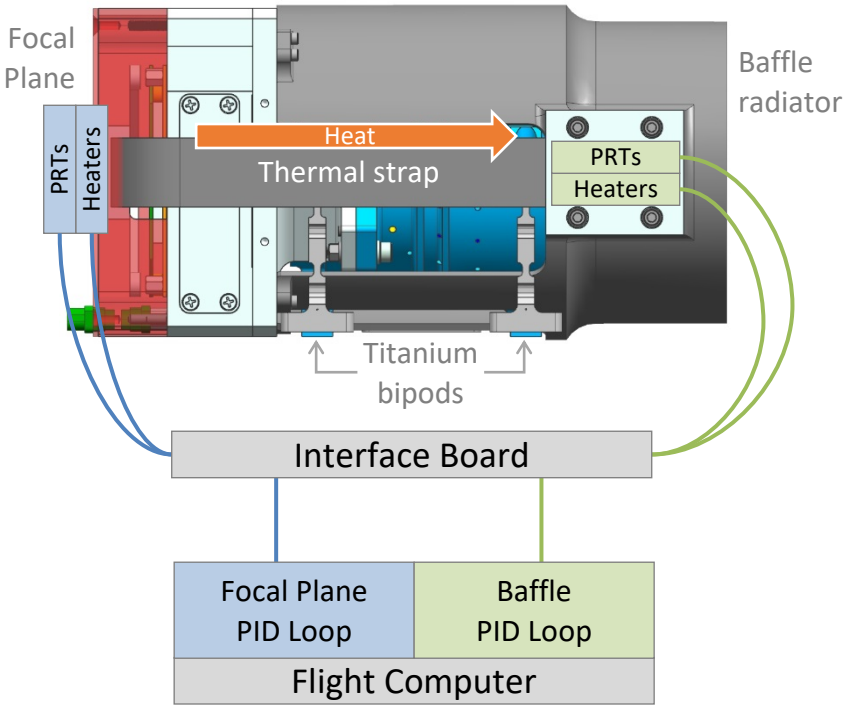
Pointing Control Results

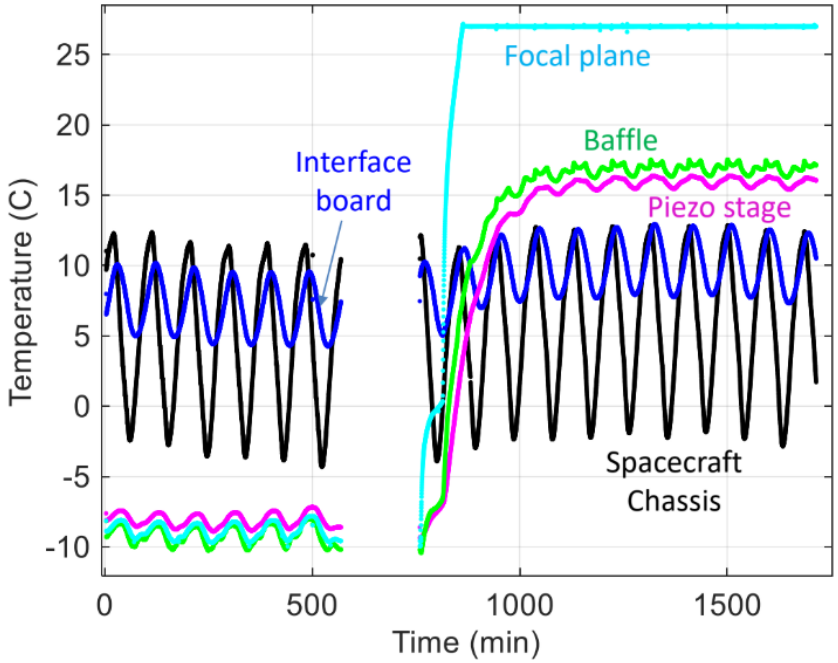
Achieved pointing error < 0.5 arcseconds RMS over 20 minutes



Thermal Control Approach

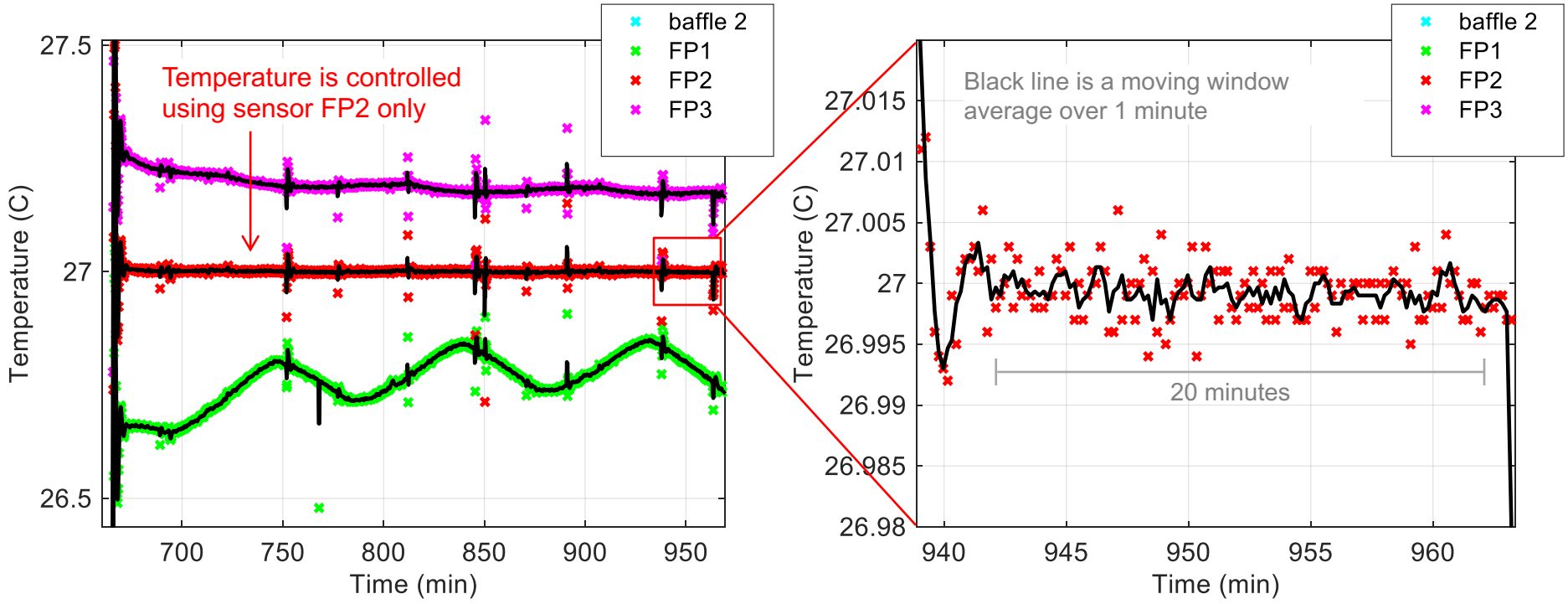
- Isolate the optical telescope from the spacecraft
- Use the baffle as a radiator
- Closed-loop heating at two locations





Thermal Control Results

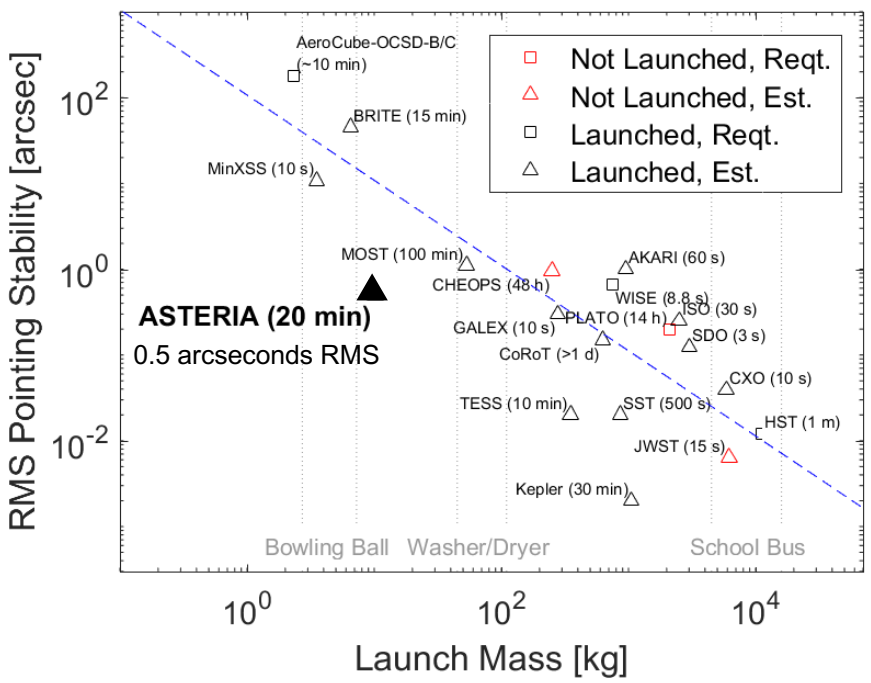
Achieved focal plane thermal control < ±0.01 K over 20 minutes



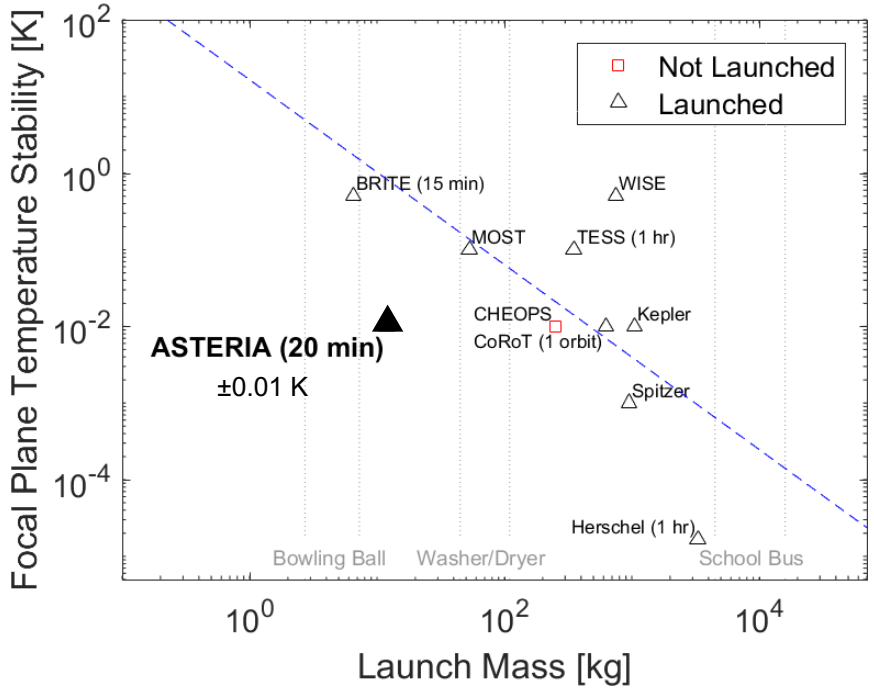
Pointing and Thermal Control Comparison

Critical technologies that enable high precision stellar photometry

Pointing Stability

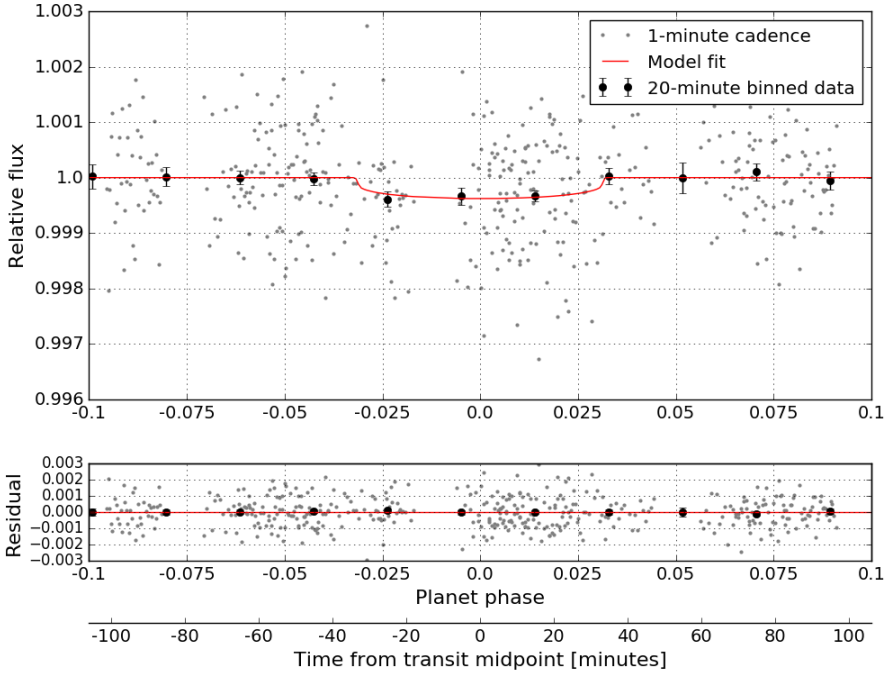


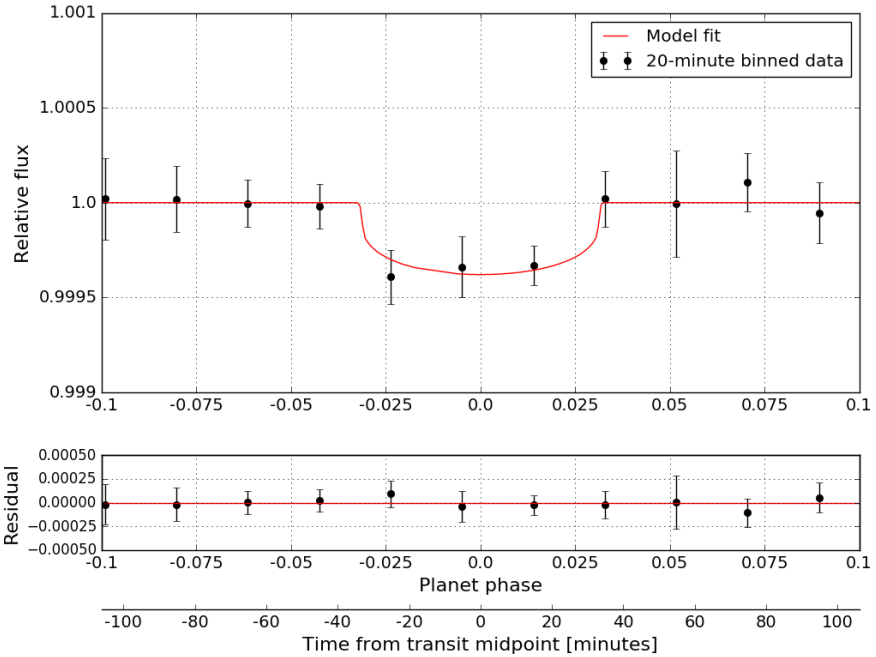
Thermal Stability



Exoplanet Transit Detection

Observed the known transit of super-Earth exoplanet 55 Cancri e





- 410 ppm transit observed at SNR=3
- $2R_E$ exoplanet around a V=5.95 Sun-like star
- The above plot contains 526 minutes of cumulative observation time, phase folded
- Each observation is approximately 20 minutes long, with 7 observations fully in-transit

Extended Mission Observation Campaign

Primary Target: HD 219134

- Goal: Look for transits of planets d and f (mini-Neptunes previously discovered via radial velocity)
- Closest, brightest known transiting exoplanet system (b and c)
- Closest transiting compact multiple system around Sun-like star

NASA/JPL-Caltech/DSS (https://photojournal.jpl.nasa.gov/jpeg/PIA19832.jpg)

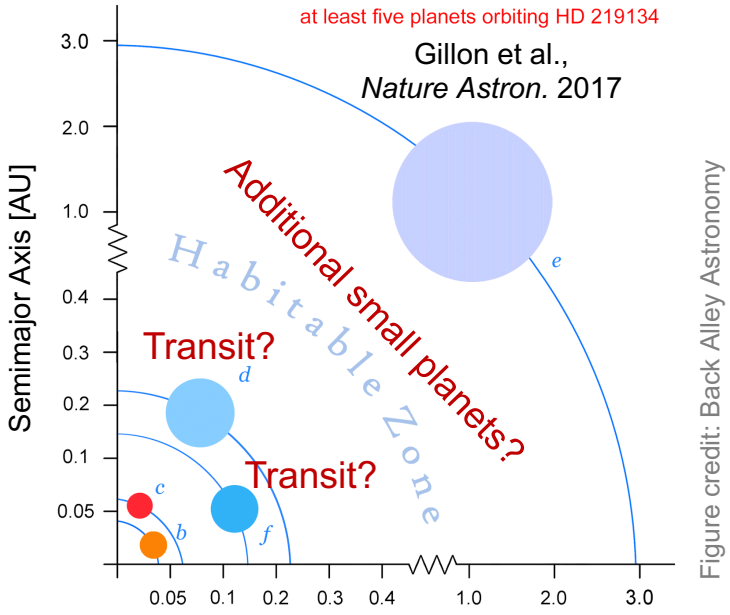
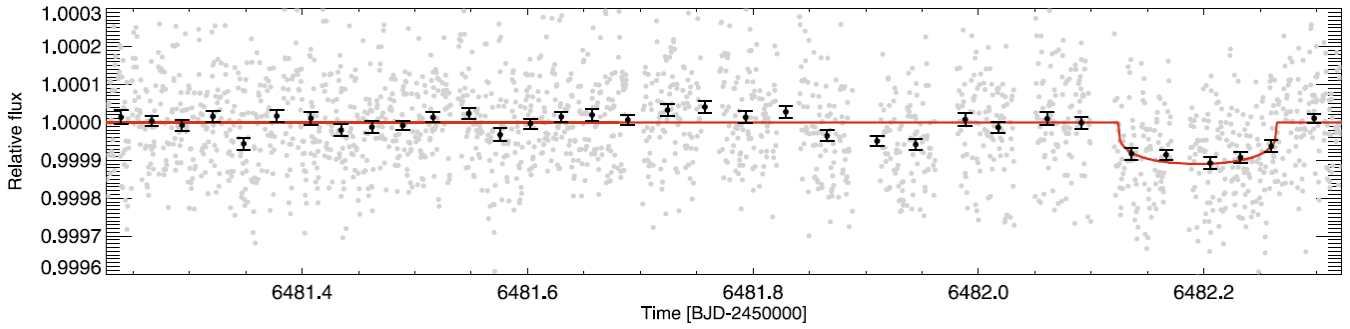


Figure credit: Back Alley Astronomy

Extended Mission Observation Campaign

Secondary Target: Alpha Centauri

- Goal: Conduct high precision observations over long time baseline to search for transiting super-Earths
- Nearest Sun-like neighbor
- Intriguing single transit-like event observed by HST by Demory et al. in 2015
- Difficult to achieve sufficient photometric precision from ground or space due to atmosphere, saturation limits, high demand for HST/Spitzer time



HST single event (Demory et al., *MNRAS* 2015)

Conclusion

- Achieved significantly improved pointing and thermal control for small spacecraft
  - Pointing stability: 0.5 arcseconds RMS over 20 minutes
  - Pointing repeatability: 1 milliarcsecond RMS from orbit to orbit
  - Thermal stability: ±0.01 K over 20 minutes at the focal plane
- Observed the known transit of 55 Cancri e, offering a proof-of-concept for performing astrophysical measurements using a nanosatellite platform
- Currently engaged in an observation campaign to seek new exoplanet transits
  - HD 219134 d and f (prior detections via radial velocity)
  - Alpha Centauri (prior transit-like signal from HST)

Questions